PATENT SPECIFICATION

(11) 1424337

1424337

(21) Application No. 59903/72 (22) Filed 28 Dec. 1972
(31) Convention Application No. 213479 (32) Filed 29 Dec. 1971 in
(33) United States of America (US)
(44) Complete Specification published 11 Feb. 1976
(51) INT CL² B29C 17/00 B29D 21/00 5/00//31/00
(52) Index at acceptance
B5A 1R100 1R10 1R14C1C 1R14C1X 1R14C2 1R14D 1R24X 1R38 1R51 1R53 1R58 1R64 1R78 9
A4K 2B3A 2C2X
A4S 1F 1G
A4X 15

(19) THE PATENT OFFICE LONDON

(54) ARTICLE HAVING BRISTLE-LIKE ELEMENTS AND PROCESS FOR MAKING SAME

(71) We, UNION CARBIDE CORPORATION, a corporation organized and existing under the laws of the State of New York, United States of America, residing at 270 Park Avenue, New York, State of New York 10017, United States of America, (assignee of WALTER HENRY SMAROOK), do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the art of forming or shaping objects from thermoformable materials.

Bristled articles such as brushes, artificial turf, belt surfaces having bristle-like configurations, and the like are common articles of commerce. Such articles usually comprise, structurally, a backing member which supports the bristle members, and from which the bristle members project vertically. In the manufacture of such bristled articles the bristle members and the backing members are usually each manufactured in a separate operation, and then the bristle members are affixed to the backing member in an additional operation. The bristled members may be affixed to the backing members in various ways, such as with adhesives, stapling means, or by a weaving type operation. In most cases, the bristle element is also made of a different material than that used for making the backing material. Thus, the need for using these different materials of construction, and the need for a plurality of fabricating operations, greatly increases the cost of the resulting product, and severely complicates the manufacturing process.

In some cases, plastic brushes can be injection molded in one operation so that the bristles and the holder are made of the same material. This procedure, however, requires the use of resins having relatively low melt indexes, expensive molds and a high pressure inection molding process.

Bristled articles are made from thermoformable material in a relatively facile manner by pulling a sheet of thermoformable material, while it is in a fused state, between a top and bottom mold plate; the top mold plate having a pattern of channels in the face thereof, and the bottom mold plate being smooth surfaced. A backing member for the bristled article results at the interface between the sheet of plastic and the bottom mold plate, and bristle elements projecting vertically from such backing member result at the interface between the sheet of plastic and the top mold plate

The present invention may provide integrally formed bristled articles made from thermoformable materials.

Also the present invention may provide an essentially one step, low pressure, process wherein bristled articles may be readily formed integrally from thermoformable materials, using assembly line techniques, and without the use of adhesives.

With respect to the herein provided description, examples and claims relating to the present invention the following definitions apply:

"Thermoformable" means that the thereby described material is a solid at 25°C. which can be reshaped or reformed above some higher temperature.

"Thermoplastic" means that the thereby described material is a solid at 25°C. which will soften or flow to a measurable degree above some higher temperature.

"Thermoset" means that the thereby described material is a solid at 25°C. which will not soften or flow, or cannot be reformed, at any higher temperature.

"Crystalline" means that the thereby described polymeric material exhibits a definite X-ray pattern for at least 50% of its polymeric structure when subjected to X-ray analysis.

"Amorphous" means that the thereby described polymeric material is devoid of a

definite X-ray pattern for more than 50% of its polymeric structure when subjected to X-ray analysis.

"Ta" means the temperature at which a thermoplastic material exhibits hot tack adhesion.

"Tm" means, with respect to a crystalline polymer, the melting point of such polymer.

"Tg" means, with respect to an amorphous polymer, the temperature at which such polyber changes from a brittle to a rubbery condition. In a crystalline polymer it is the temperature at which the polymer becomes glassy, or the crystallinity disappears.

"Plastic" means a natural or synthetic resin.

"Normally solid" means solid at 25°C.

"Wet" or "Wetting" means the relative ability of one material to achieve interfacial contact with another material.

"Hot tack adhesion" means the ability of one material to exhibit adhesion to a second material while the first material is in a molten state, above its Tm or Tg.

"Fusion point" means a temperature at which a material softens or melts.

"Cohesive Flow Property" means the property of a material in the molten state to be so readily distorted by external forces that the geometric cross-sectional area of such material will change substantially under such forces.

"Heat Distortion Point" means the temperature of a material as measured by ASTM D-648.

Most thermoformable materials have a Ta, i.e., a temperature at which they will exhibit hot tack adhesion to other materials. In the case of crystalline polymeric materials this Ta occurs about 5 to 10°C. above the Tm of such polymeric materials.

In the case of amorphous materials the Ta varies considerably, depending on the structure and molecular weight of the material. For the amorphous polymers, therefore, the Ta may be about 30 to 150°C. above the Tg of such polymers.

The Tm or Tg will also vary for a given polymeric backbone, depending on the molecular weight and density of the polymer.

The following is a listing of various polymeric materials which may be used in the present invention with a listing of their Tm or Tg, and their Ta, in °C. The Ta values reported herein were specifically determined with respect to the adhesion of the polymeric material to an aluminum substrate. Essentially the same Ta value will be obtained upon adhering the polymers to other substrates.

Polymer	Tg	Tm	Ta
1. polyethylene Density=0.96 M.I.=3—5	—	126	135—140
2. polyethylene Density=0.94 M.I.=12—15	—	122	130—135
3. polyethylene Density=0.924 M.I.=1.2	—	100—108	120
4. polyvinyl chloride	>5	—	155
5. Nylon-6	60	215—220	240
6. Nylon-6,6	65	260	270
7. Polycaprolactone	—	58	60
8. Polyurethane (polyether)	—	130—170	160—180
9. polysulfone	185	—	300
10. polypropylene	−5 to 0	165—170	170
11. polycarbonate	150	—	225
12. polymethylmethacrylate	90	—	160
13. polystyrene	100	—	185
14. polystyrene (impact grade)	100	—	180

	Polymer	Tg	Tm	Ta
15.	polyacetal	−60	165	170
16.	90/10 mol % copolymer of polymethacrylonitrile & styrene	115	—	240
17.	70/30 mol % copolymer of polyvinyl alcohol and polyvinyl acetate	50—60	—	120—130
18.	94.2/5.7 mol % copolymer of ethylene and ethyl acrylate	−20	—	110
19.	91.8/8.2 mol % copolymer of ethylene and acrylic acid	18	—	110
20.	82/18 wt % copolymer of ethylene and vinyl acetate M.I.=2.3	−15	—	120
21.	styrene-butadiene copolymer	90	—	190
22.	styrene acrylonitrile copolymer	100	—	190
23.	hydroxy propyl cellulose	100	—	110
24.	(solution blend of) polystyrene and polyphenylene oxide	115—120	—	235
25.	cellulose acetate	120	—	170
26.	acrylonitrile-butadiene styrene terpolymer	98	—	180

According to our copending Application No. 59800/72 (Serial No. 1,424,334) there is described and claimed a process for expanding the cross section of a blank of thermoformable material with the attendant formation of one or more voids of reduced pressure within said cross section which comprises venting said voids during the increasing of the cross section so as to equilibrate the pressure within said voids with the pressure without said blank and thereby regulate the uniformity and integrity of the resulting cross-sectional geometry of the expanded blank.

According to our copending Application No. 59902/72 (Serial No. 1,424,336) there is described a process for expanding the cross section of a blank of thermoformable material by pulling said blank between a pair of oppositely positioned mold plates, said blank having residual strains and stresses therein, which comprises annealing said blank to remove said strains stresses therefrom prior to said pulling.

According to our copending Application No. 59901/72 (Serial No. 1,424,335) there is described and claimed an article comprising an integrally formed, three dimensional panel comprised of thermoformable material said panel having a near side and a far sode, the cross section of said panel comprising a plurality of cells, each of said cells having one end narrower than the other, and each cell being open at its wider end, and closed at its narrow end, the wider, open end of each cell having a continuous lip member projecting inwardly from the walls of said cell, approximately one half of said cells having their open ends facing out from the near side of said panel, and the remainder of said cells having their open ends facing out from the far side of said panel.

According to our copending Application No. 59901/72 (Serial No. 1,424,335) there is described and claimed a process for expanding the cross section of a blank of thermoformable material by pulling said blank, while in a thermoformable state, between a pair of perforation means,

each of said perforations means providing perforations adjacent the interface contact between said perforation means and said blank, and the perforations in one perforation means being non-aligned with the perforations in the other perforation means,

said expanding being attendant by the formation of one or more voids of reduced pressure within the cross section of the expanding blank,

the pattern of occurrence of such voids being in response to the pattern of perforations in said perforation means,

which comprises venting said voids during said expanding so as to equilibriate the pres-

sure within said voids with the pressure without said blank and thereby regulate the uniformity and integrity of the resulting cross-sectional geometry of the expanded blank.

According to our copending Application No. 59797/72 (Serial No. 1,424,333) there is described and claimed a multicell article integrally formed from thermoformable material and comprising

a continuous base member,

a plurality of wall members projecting vertically from said base member and defining a plurality of cells,

each of said cells being open at the top thereof, and sealed at the base thereof by said base member, and having the sides thereof defined by a plurality of said wall members, with adjoining cells sharing common wall members, and

each of said cells having at its open end a continuous lip member proecting inwardly from all of the wall members defining the sides of said cell.

According to our copending Application No. 59797/72 (Serial No. 1,424,333) there is described and claimed a process for integrally forming a multicell article from a blank of thermoformable material having a Ta in the form of a sheet having a top surface and a bottom surface which comprises

positioning said blank between a top mold plate and a bottom mold plate, each of said mold plates having a surface for contacting the top and bottom surfaces of said blank, and each of said mold plates having a fusion point which is higher than the Ta of said thermoformable material.

The blank contacting surface of said bottom mold plate being continuous, and perforation means being used to provide a pattern of perforations at the interface between the top surface of said blank and the blank contact surface of the top mold plate, such pattern providing areas of contact and non-contact between the top surface of the blank and the blank contact surface of the top mold plate when said mold plates are brought into contact with said blank, bringing said plates together so as to cause them to contact said surfaces of said blank, heating said blank to its Ta adhesively bonding said blank by hot tack adhesion to the blank contacting surfaces of said mold plates,

pulling said mold plates apart while said blank is thus adhesively bonded thereto so as to draw a portion of the thermoformable material from the blank in the form of a plurality of multiwalled cells having common walls therebetween and open ends defined by said pattern of perforations,

said pulling apart effecting partial vacuum conditions within said cells,

venting said cells during said pulling apart so as to equilibrate the lower level of pressure within said cells with the higher level of ambient pressure without said cells so as to thereby regulate the uniformity and integrity of the configuration of the cells,

cooling the resulting expanded blank to a temperature below the heat distortion temperature of said thermoformable material, and

separating the cooled expanded blank from said mold plates.

According to our copending Application No. 37955/75 (Serial No. 1,424,340) there is described and claimed an article formed from a preform or blank having an expanded lattice or network configuration of thermoformable material, said thermoformable material having a Ta, said article having a cross-section comprising a plurality of strands having an essentially I beam configuration formed by expanding the cross-section of said preform or blank.

According to our copending Application No. 59906/72 (Serial No. 1,424,339) there is described and claimed a process for expanding the cross-section of a preform or blank having a lattice or network configuration formed from a thermoformable material exhibiting a Ta which comprises positioning said preform or blank between a pair of platens while said preform or blank is heated to a temperature which is $\geq$the Ta of said thermoformable material, each of said platens having surfaces which are adapted to contact said preform or blank and to being wet by said thermoformable material at such contact surfaces at $\geq$ the Ta of said thermoformable material bringing said platens together so as to cause them to contact said surfaces of said preform or blank.

adhesively bonding said preform or blank by hot tack adhesion to said contacting surfaces of said platens,

pulling said platens apart, while said preform or blank is thus adhesively bonded thereto, so as to thereby expand the cross-section of said preform or blank,

cooling the expanded preform or blank to a temperature below thte heat distortion temperature of said preform or blank, and

separating the cooled, expanded preform or blank from said platens.

According to our copending Application No. 59904/72 (Serial No. 1,424,338) there is described and claimed a device for expanding the cross-section of thermoformable material which comprises a first mold plate and a second mold plate, each of said plates having a surface for contacting said thermoformable material when said thermoformable material is inserted between said plates, said surfaces having a fusion point of $\geq 70°C$. and being adapted to bond in a non-molten state, to thermoformable material having a Ta by hot tack adhesion of the Ta of said thermoformable material, at least one of said mold plates being adapted to vent air through a portion thereof during the expanding of

said thermoformable material between said plates by pulling said plates apart while said thermoformable material is bonded thereto by hot tack tension, means to heat said plates to the hot tack adhesion temperature of said thermoformable material and means to pull said plates apart while said thermoformable material is bonded thereto.

It has now been found that an article having bristle like elements may be readily formed by expanding the cross-section of a sheet of thermoformable material between a pair of separable mold plates, one being a top mold plate having a pattern of channels or grooves in the face thereof, and the other being a continuous faced bottom plate. The expansion of the sheet is conducted while the sheet is heated so as to place the thermoformable material in a thermoformable state, i.e., the sheet is heated to a temperature which is $\geq$ the fusion point of the thermoformable material. The mold plates are moved apart to effect the desired expansion of the sheet of thermoformable material into the form of an article having bristle-like elements while the sheet is attached to the surfaces of the mold plates as disclosed below.

According to the present invention there is a process for integrally forming a bristled article from a blank of thermoformable material having a Ta in the form of a sheet having a top surface and a bottom surface which comprises inserting said blank between a top mold plate and a bottom mold plate, each of said mold plates having a surface for contacting the top and bottom surfaces for contacting the top and bottom surfaces of said blank, and each of said mold plates having a fusion point which is higher than the Ta of said thermoformable material, the blank contacting surface of said bottom mold plate being continuous, and the blank contacting surface of said top mold plate having a pattern of channel means therein, said channel means being used to provide a pattern of channels at the interface between the top surface of said blank and the blank contact surface of the top mold plate, such pattern providing areas of contact between the top surface of the blank and the blank contact surface of the top mold plate at the non-channelled areas of said top mold plate, and such pattern also providing areas of non-contact between the top surface of the blank and the blank contacting surface of the top mold plate at the channelled areas of said top mold plate, heating said blank to at least its Ta so as to adhesively bond said blank by hot tack adhesion to the blank contacting surfaces of said mold plates, pulling said mold plates apart while said blank is thus adhesively bonded thereto so as to draw a portion of the thermoformable material from the blank in the form of a plurality of discrete bristle-like elements, the pattern of occurrence of said bristle-like elements, being determined by the pattern areas of contact between the top mold plate and the blank, said pulling apart effecting partial vaccum conditions between said bristle-like elements, venting said channels during said pulling apart so as to equilibriate the lower level of pressure within said channels with the higher level of ambient pressure without said channels so as to thereby regulate the uniformity and integrity of the configuration of the bristle-like elements cooling the resultant expanded blank to a temperature below the heat distortion temperature of said thermoformable material.

The preferred embodiment of the process of the present invention is based upon the property of various materials, and particularly thermoplastic polymeric materials, to exhibit hot-tack adhesion to practically all substrates at a temperature, Ta, which is usually above the Tg or Tm of the thermoplastic polymeric material. Thus, in a fused or molten state, the thermoplastic polymeric material will wet out practically all substrate surfaces and thereby impart adhesion thereto. In some cases this adhesion phenomena will be lost when the thermoplastic polymeric material cools below its Tm or Tg.

Thus, if a blank of thermoplastic polymeric material is placed between two mold plates of the heated press so that the temperature of the mold plate is about 5 to 10°C. above the Ta of the polymeric material in the blank, and the mold plates mechanically separated apart, the adhesive forces of the polymeric material to the surfaces of the mold plates are greater than the cohesive flow properties of the polymeric material itself during the plate separation or expansion step. As a result, it is possible to mechanically move the mold plates a certain distance apart with the polymeric material bonded to the surfaces thereof without causing a rupture of the adhesion between such surface and the fused material.

Although the mass of the expanded fusible material does not change, the cross-sectional configuration of the fusible material is expanded in the direction of the two separated plates as a result of the adhesive force of attraction between the fused thermoformable material and the surfaces of the plates. The extent to which the cross-sectional area of the fused material can be so expanded is thus primarily determined by the strength of the adhesive bond between the fused material and the surfaces of the mold plates, and the extensibility, in the molten state, of the thermoplastic resin in the blank. The stronger is such adhesive bond, the greater is the amount of cohesive flow that can be induced in the molten resin without a rupture of the adhesive bond occurring. The strength of the bond will thus depend on the nature

of the thermoplastic resin in the blank, the nature of the mold plate materials, the extent of the surface area of the mold plate which is in contact with the fused blank and the cohesive strength and flow properties of the polymeric plastic.

Thus, the use as mold surfaces, of materials which are more readily wet by the fused plastic blank, will allow for a wider separation of the mold surfaces with the fused plastic bonded thereto, than would the use of mold surfaces made from materials which are not as readily wet by the fused blank. Also, the use of the blank in the form of continuous sheet material will allow for the wetting with the blank of a larger amount of the surface area of the faces of the mold plates and thus allow for the attainment of greater adhesive forces between the fused blank and the mold plates.

As the mold plates are pulled apart with the heated thermoformable material bonded thereto, voids of reduced pressure are formed within the body of the expanding plastic. Thus, although the mass of plastic does not change, the volume of the expanding cross-section of the plastic does increase. The frequency of the occurrence of these voids, as well as their size and shape, i.e., the pattern of the voids, is largely determined by the pattern of the points or areas of contact which exist between the mold surfaces and the expanding plastic during the expansion process. In order to maintain the desired pattern of the voids, it is necessary to vent the voids during the expansion step so as to equilibrate the pressure within the voids with the pressure without the expanding material.

The pattern of the points or areas of contact between the mold surfaces and the thermoplastic blank can be readily varied.

For the purposes of the present invention the means for providing such pattern of contact can be generally characterized as channel means and such channel means are used to provide a pattern of inter-connected channels at the interface between the top surface of the blank and the blank contact surface of the top plate when the blank is inserted in the press between the top plate and the bottom plate. In the preferred mode of operation of the process of the present invention the pattern of the areas of contact between the surfaces of the mold plates is preferably provided by using, as the bottom plate, a continuous faced plate, and, by using as the top plate, a plate having a pattern of interconnected recessed channels or grooves therein as the channel means. The bottom plate will thus provide continuous contact with the entire surface of the sheet facing such bottom plate. The channeled top plate will only provide contact with the surface of the sheet facing such top plate at the non-channeled areas of such top plate.

The desired pattern of contact areas can also be supplied to the contact surfaces of the top mold plate or the sheet with other channel means. A negative of the desired pattern can be used as such other channel means and it can be affixed to the contact surface of the sheet which is to contact the top mold plate or affixed to the contact surface of the top mold plate itself, in the form of masking means, such as cut-outs in the form of a grid of masking tape, kraft paper, "Mylar film" ("Mylar" is a registered Trade Mark) or other materials which will prevent the fused thermoplastic materials from adhering to the surface of the top mold plate. Thus, the fused plastic will only be allowed to adhere to the surface of the top mold plate at those areas of contact between the surface of the top mold plate and the sheet where there is no masking means present.

These "negatives" thus function, when used as channel means in the process of the present invention, in a manner of procedure which is directly opposite to that of the channeled top mold plates, the use of which as channel means is discussed above. These "negative" channel means thus prevent contact at the interface between the top surface of the blank and the contact surface of the top mold plate at those places at the interface where such "negative" channel means are present. The use of the channeled top mold plates, on the other hand, provides a lack of contact at such interface where the blank contact surface of the top mold plate is not present, i.e., at the areas of the interface of the channels or grooves in the top mold plate. Each of these two types of channel or groove means, does, however, function in the same basic manner, that is, each provides a pattern of interconnected channels in the interface between the contact surface of the top mold plate and the top surface of the blank.

Thus, it may be said that the cross-sectional geometry of the expanded sheet is a function of the design of the areas of contact which is provided in the contact surface of the top mold plates or the surface of the blank which is to contact the top mold plate. It is such design which determines the extent to which the surface areas of tthe top mold plate and tthe blank are kept in contact during the expansion step in the process, and the extent of such contact areas is what determines the pattern of the voids or channels in the expanding blank or sheet, and thus, in the cross-sectional geometry of the resulting article having bristle-like elements.

The voids or channels created in the sheet during the expansion step are vented through the channels or grooves in the top mold plate, or in the case of the use of negative perforation means, the voids or cells are

vented from tthe outside of the blank and between the negative and the mold plate. Venting of the negative perforation means may also be accomplished by providing a vent hole over the negative perforation means which vent hole would be vented through the mold plate to the atmosphere.

The speed with which the mold plates are moved apart during the expansion of the blank is not critical. The speed to be used is governed by the cohesive flaw properties of the thermoformable material used in the fused blank. Where the blank is used in the form of a sheet having thicknesses of the order of about 40 to 300 mils, such blanks may be expanded $\geq$ to 20 times such thicknesses according to the present invention by expanding the fused blank at a rate of separation of the mold plates of about 10 to 150 mils per second.

After a desired separating distance has been achieved, the expanded blank is cooled, to a temperature below the heat distortion point of the plastic, the press is opened and the expanded blank is removed therefrom. At this point the expanded blank may or may not continue to adhere to the surfaces of the mold plates, depending on the nature of the mold surfaces and the polymeric materials, as will be discussed below.

The expanded blank is cooled to a temperature below its heat distortion point, before being removed from the press so as to freeze, so to speak, the configuration of the expanded blank, and thus prevent distortion of such configuration.

Thus in the preferred embodiment of the process of the present invention the cross-section of the blank of thermoformable material having a Ta is expanded between a pair of mold plates so as to provide an integrally formed article having bristle-like elements in the following sequence of steps:

The blank, in the form of a continuous or non-continuous sheet having a top surface and a bottom surface, is inserted between a top mold plate and a bottom mold plate, with each of the plates having a surface for contacting the blank, and each of the plates having a fusion point which is higher than the Ta of such thermoformable material,

the blank contacting surface of the bottom mold plate being continuous, and channel means being used to provide a pattern of interconnected channels at the interface between the top surface of the blank and the blank contact surface of the top mold plate, such pattern providing areas of contact and non-contact between the top surface of the blank and the blank contact surface of the top mold plate,

the blank is bonded by hot tack adhesion to the sheet contacting surfaces of the mold plates,

the mold plates are pulled apart, while the blank is thus adhesively bonded thereto so as to draw a portion of the thermoformable material from the blank in the form of a plurality of discrete bristle-like elements, the pattern of occurrence of such bristle-like elements being determined by the pattern of areas of contact between the top mold plate and the blank,

the pulling apart of the blank effecting reduced pressure conditions within the channels,

venting the channels during such pulling apart so as to equilibrate the pressue within the channels with the pressure without the channels so as to thereby regulate the uniformity and integrity of the configuration of the bristle like elements,

cooling the resulting expanded blank to a temperature below the heat distortion temperature of the thermoformable material, and

separating the cooled expanded blank from the mold plates.

The mold plates which are to be used may be disengageable from the device used to move them apart during the expansion step of the process described above. One or both of the mold plates can also be more permanently affixed to such device, in which case, the cooled, expanded thermoformable material is then removed from the device and the mold plate(s) affixed thereto.

When the expanded blank is cooled below its Ta, or even below its Tm and/or Tg, it will not necessarily, in all cases, automatically lose its adhesion to the surfaces of the mold plates. The expanded blanks which are made of materials which are non-polar in nature, such as the polyolefines, will generally readily lose their adhesion to the surfaces of all of the types of mold plates which may be used in the process of the present invention, and which are listed below in more detail. The expanded blanks which are made of polar materials, i.e., materials comprising compounds which possess an electric moment, such as polysulfone resins and resins containing carboxyl, hydroxyl and ester groups, will tend to remain bonded to the surface of most, if not all, of the mold plates which may be used in the process of the present invention. However, even where adhesion between the expanded blank and the mold plates is not automatically lost upon cooling the expanded blank, the cooled expanded blank, can be mechanically stripped from the mold plates without disrupting the integrity or configurations of the expanded blank.

In addition to the use of hot tack adhesion, other means may be used for affixing the thermoformable material to the mold plates during the expansion of the cross-section of the thermoformable material. In one such other procedure the thermoformable material may be loaded with a filler which is susceptible to being magnetized such as, powdered

iron and barium ferrite, and the thus filled thermoformable material may be affixed to the mold plates during the expansion step, in any desired pattern of points or areas of contact therebetween by applying a magnetic field to selected portions of the contact surfaces of the mold plates. The thermoformable material may also be affixed to the surfaces of the mold plates during the expansion step by the application of electrostatic forces between the expanding thermoformable material and selected contact areas of the surfaces of the mold plates. Regardless of the means used to affix the thermoformable material to the mold plates during the expansion step, the thermoformable material must be heated to a fused or molten state during the expansion step.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 shows, in perspective, a top mold plate which may be used in the process of the present invention.

Figures 2 to 4 show a sequence of steps involved in forming an article having bristle-like elements from a sheet of thermoformable material according to one embodiment of the present invention, using a mold plate as shown in Figure 1 as a top mold plate.

Figure 5 shows a top view, and figures 6 and 7 show cross-sectional views, of an article having bristle-like elements made with a top mold plate as shown in Figure 1 and a continuous faced bottom mold plate.

Figure 8 shows a cross-sectional view of an article having bristle-like elements used as a cushioning device.

Figures 9 to 11 show the use of expanded articles of the present invention as racks or cradles.

Figure 12 shows the use of expanded articles of the present invention as a zipper-like device.

A better understanding of the process of the present invention can be obtained from the process sequences illustrated in Figures 1 to 4 of the drawings.

Figure 1 shows a perspective view of a top mold plate 1 which resembles the face of a waffle iron and may be used in the process of the present invention. Mold plate 1 has a series of interconnected recessed channels or grooves 2 cut into the top of such plate. Elevated areas 3 at the top surface of mold plate 1 are defined by the grid-like pattern of channels 2, and elevated areas 3 serve as the blank contact surface of mold plate 1. Channels 2 serve as the channel means. The channel means need not be used in a grid pattern. The channel means can be a series of parallel channels or grooves running in one direction across the face of mold plate 1. In the top mold plate 1 shown in Figure 1 contact surfaces 3 comprise a series of aligned rows and columns of rectangles, with each rectangle being separated from the others by recessed channels or grooves 2 that run the length and width of the top surface of mold plate 1.

Figures 2 to 4 show a sequence of steps involved in using top mold plate 1 according to one embodiment of the process of the present invention. In Figure 2 there is shown a blank 4 of thermoformable material having a Ta, in the form of a smooth surfaced sheet of such material, which is inserted between the open platens, 5A and 5B, of a Carver press. To the face of upper platen 5A of the press there is attached a top mold plate 1 with the face having contact areas 3 therein facing down. In the embodiment shown, the continuous upper surface of lower platen 5B functions as the bottom mold plate contact surface which will contact the lower contact surface of the blank 4 during the expansion process Top mold plate 1 and platens 5A and 5B are heated, for the purposes of the present invention, to a temperature which is about 5 to 10°C above the Ta of the blank 4 Top. mold plate 1 and the platens 5A and 5B may be heated before, preferably, or after the blank is inserted in the press. Top mold plate 1 is preferably heated conductively through platen 5A.

The Carver press described herein is a 20 ton hand operated hydraulic ram 6 which actuates a movable lower platen 5B against a fixed upper platen 5A. In other presses, the upper mold pattern can be movable with the lower platen fixed, or both platens can be movable. The platens are usually heated electrically. Although the Carver press is the preferred means for bringing the heated mold plates and platens into contact with the blanks, according to the present invention, other suitable devices may be used, such as heated belts.

The process of the present invention may be conducted continuously or discontinuously. Using devices such as the Carver press, the process is readily conducted discontinuously. The process may be conducted continuously by feeding a continuous blank of thermoformable material between a pair of heated continuous belts of materials suitable as mold surfaces.

Figure 3, shows the press after it has been closed with sufficient pressure to cause the top mold plate 1 and bottom mold platen 5B to exert a slight pressure on blank 4 so as to cause the heated blank to wet the contact surfaces 3 of top mold plate 1 and bottom mold platen 5B which come in contact with the blank. The amount of pressure required for this step is of the order of about 1 ounce to 4 pounds per square inch. The pressure causes the blank to be slightly compressed.

Figure 4 shows the platens pulled apart after the expansion step, with the expanded blank 7 adhering to points or areas of contact with plate 1, at areas 3 thereof, and platen 5B.

During the expansion step, as will be discussed in more detail below, areas of reduced pressure or voids 8 arise within the cross-section of the expanding blank 7. The side walls of the individual voids 8 are defined by rib-members or strands 9 of the expanded blank. The limits of voids 8 are defined by the contact surface 3 of top mold plate 1, side walls 9 and base member 10 of expanded blank 7. The reduced pressure in voids 8 is caused by the fact that each void 8 tends to become a sealed chamber when the blank 4 fuses to the contact surfaces 3 of top mold plate 1 and bottom mold platen 5B, and as the mold surfaces are pulled apart, the sealed voids 8 become enlarged, thus creating areas of reduced pressure. To prevent the higher ambient pressures from distorting or rupturing expanded walls 9 of the blank 7, voids 8 of the blank 7 are vented during the expansion step so as to equilibrate the pressure within such voids 8 with the ambient pressure outside the blank 7. This venting tends to preserve the pattern and the integrity of the resulting cross-sectional geometry of the expanded blank. In this embodiment of the present invention, the venting is accomplished through the channels 2 in top mold plate 1 and the ambient atmosphere by venting these channels to the outer edges of the mold plate.

During the molding or expansion step in the process and lower surface of the expanding blank adheres to the upper surface of platen 5B and this causes the formation of continuous base member 10 of expanded blank 7. Similarly, the upper surface of the expanding blank adheres to the contact surfaces 3 of top mold plate 1 and this causes the formation, upon expansion of the blank, of I beam shaped strand or rib members 9, each of which has a head member 11 at the top thereof, and at the lower end thereof is integrally joined to continuous base member 10.

After the mold plates have been expanded the desired distance they are cooled to a temperature which is below the heat distortion point of the plastic in the blank. The cooling may be allowed to occur in the ambient air, or by circulating a cooling medium through the platens, or in some cases by a liquid coolant spray, or by conduction through cooled platens, or by a combination of such procedures.

The mold plates may be readily disengageable from the rest of the press so as to allow another set of mold plates to be inserted and used in the press with another blank of thermoformable material while a previously used set of mold plates having an expanded blank therebetween is allowed to cool. Where the bottom mold plate is to be disengageable from the rest of the press it is preferable to use a separate sheet of metal or other suitable mold plate material having a continuous blank contact surface, rather than attempt to use the lower platen of the press for this purpose as shown in Figures 2 to 4 above.

Figure 5 shows a top view, and Figures 6 and 7 provide cross-sectional views, of expanded blank 7, after the expanded blank was removed from the press and subjected to a further process step as will be described below. The top view of expanded blank 7, as shown in Figure 5, provides a partial replication of the pattern of contact surfaces 3 of the upper mold plate 1 of the press to which it adhered during the expansion step. This pattern is shown replicated in the pattern of columns and rows of rectangular shaped head members 11 depicted in the upper half of expanded blank 7 in Figure 5. Each of these rectangles is the head 11 of an expanded I beam shaped rib member 9 as shown in cross-section in Figure 6 or 7. The base 10 of expanded blank 7 is a continuous film of plastic which forms the base for each and every rib member 9. During the expansion step in the process, the resulting voids, in the form of voids 8 between expanding rib members 9, are vented through the ends thereof, out the sides of the expanding blank.

After the expansion operation the head member 11 of some of the rib members 9 were removed so as to provide bristle like members RA as shown in cross-section in Figures 6 and 7.

For aesthetic, or other purposes, it may be desired to expand the cross-section of the blank in a non-uniform manner so as to provide expanded blanks which have cross-sectional areas of various degrees of thickness. In the expanded blank 7 shown in figures 5 to 8, all rib members 9 were expanded to the same uniform height. The height of these rib members is adjusted by the extent to which the blank is pulled apart during the expansion step in the process of the present invention. The blank is usually pulled apart so that the rib members are at least longer than they are wide.

The article having bristle-like elements thus formed in an integral manner, e.g., from a single compound or composition and in an essentially one step forming process, may be said to comprise

a continuous base member, and

a plurality of strand of bristle-like members projecting vertically from at least one side of such base member, with each of such strand members having an I beam configuration.

In the expanded blank shown in Figures

5 to 8 all of the strand or bristle-like members 9 project from the same side of base member 10, although in other embodiments bristle-like elements can be provided on both surfaces of base member 10.

The expanded blank 7 shown in Figures 5 to 7 can be used for the preparation of objects having bristle-like elements such as artificial turf, brushes, door mats, scraping devices and packaging or cushioning material. Figure 8, for example, shows a flexible expandable blank 7 rolled in the form of a circle with bristle-like elements 9, having heads 11 thereon, protruding outward. In this form, expanded blank 7 may be used as a cushioning or protective device for articles enclosed therein. The head members 11 can be removed from, or left on, rib members 9, for all of the applications in question.

Figures 9 to 12 also show various types of end-use applications for which the expanded blanks of the present invention may be employed. Figures 9, 10, and 11, for example, show the use of expanded blanks which may be used as racks or cradles for elongated items, such as glass tubing, thermometers, test tubes, piping and the like. Figure 9 shows, in perspective, a square or rectangular shaped expanded blank 12 which has a hollow area 12A. Four seams, 12B, shown by dotted lines or arrows, will be discussed below in Example 9. Expanded blank 12 has a plurality of I beam shaped bristle-like emembers 13 positioned in rows and columns on the four legs of its rectangular configuration. Bristle-like members 13 have heads 14, and all bristle-like members 13 project vertically from base 15 of the expanded blank. The hollow area 12A of expanded article 12 allows for a visual inspection and ready grouping of the elongated items, such as glass tubing 16, that may be racked or cradled thereon.

Figure 10 shows, in perspective, a circular shaped expanded blank 17 which has a hollow area 17A. Expanded blank 17 has a plurality of I beam shaped bristle-like members 18 positioned in rows and columns around the periphery thereof. Bristle-like members 18 project vertically from base 19 of the expanded blank. The hollow area of 17A of expanded article 17 allows for a visual inspection and ready grouping of elongated items, such as glass tubing 20, that may be racked or cradled thereon.

Expanded articles 12 and 17 may be used as racks, and mounted on walls, for the storing or mounting of elongated items on walls. Expanded articles 12 and 17 may also be used on a flat surface, as a cradle for elongated items mounted thereon. Where used as wall mounts, it is preferable that bristle-like elements 13 and 18 be flexible where the objects mounted on expanded articles 12 and 17 are to be readily removed from, and returned to, such mountings. Where the elongated objects are to be more permanently mounted in expanded articles 12 and 17, on a wall, then bristle-like elements 13 and 18 can be rigid.

Figure 11 shows an elongated expanded blank 21 which is used to house elongated piping or tubing 22 thereon. Expanded blank 21 has a plurality of I beam shaped bristle-like members 23 positioned in rows and columns thereon. Bristle-like members 23 project vertically from base 24 of the expanded blank. Expanded blank 21 can be used as a protective cradle for the shipment therein of elongated items such as piping, glass tubing, and the like. Bristle-like elements 23 can be flexible or rigid. Where bristle-like elements 23 are rigid, the elongated materials to be mounted therein can be inserted in, and removed from, between two rows or columns of the bristle-like elements, at the ends thereof. Where bristle-like elements 23 are flexible, the elongated materials which are to be mounted therein can be inserted in, and removed from, between two rows or columns of the bristle-like elements by pushing or pulling the elongated items past the flexible heads of the bristle-like members. The overhanging lips of the heads of bristle-like elements 23 provides a protective canopy over the elongated item cradled under such head members.

Figure 12 shows the use of two different expanded articles 25 and 29 to form a zipper-like device. Expanded article 25 is a rigid article which has rigid backing member 26 and rigid bristle-like elements 27, rigid bristle heads 28 and which may be made from plastics such as polycarbonate, polymethylmethacrylate, nylon-6, polystyrene, (rigid) polyvinyl chloride and polyethylene, as disclosed below in the examples. Expanded article 29 is a flexible article which has a flexible backing member 30, a flexible bristle-like elements 31, and flexible bristle heads 32. This flexible type of expanded article may be made from resins such as ethylene-ethyl acrylate copolymers and polyurethanes as disclosed below in the examples. These zipper-like devices exhibit good holding properties under lap shear loading conditions, i.e. when loads are applied parallel to the surfaces of backing members 26 and 30. These zipper-like devices, however, also allow for the ready separation of the flexible member 29 by the peeling of such member from the rigid member 25 as shown in Figure 12. Bristle heads 28 and 32 shown in Figure 12 are rectangular in shape.

The use of different shaped or contoured bristle heads on flexible and/or rigid articles 25 and 29 is also possible so as to provide different degrees of peel strength properties and shear load properties in the composite device. This zipper type device can be used as zipper means for packaging applications.

The expanded plastic objects made in accordance with the present invention are lightweight panels that may be rigid or flexible depending on the plastic used therein, and the degree to which the plastic is expanded. Additional rigidity may be supplied by bonding or fastening the expanded plastic member to one or more rigid lamina.

The bristle-like elements 9 were provided on expanded blank 7, as shown above, in an ordered arrangement of aligned rows and columns. Other patterns of the bristle-like elements can be provided by the use of appropriately designed contact areas in the contact surface of the top mold plate. Thus the contact areas could be designed so as to provide staggered rows and columns of such contact areas, or contact areas of different shapes and sizes or a random pattern of such contact areas. In each case, each contact surface area of the mold plate should be separated from the others by channeling means.

The materials which may be employed as the blanks in the present invention are normally solid thermoformable materials which have a Ta of about 50 to 300°C., and preferably of about 100 to 250°C.

If there is a difference of at least about 10°C. between the melting points of any two fusible materials that could be used as the mold plates, then the fusible material having the lower melting point could be used as a blank while the fusible material having the higher melting point could be used as the mold plate.

The blanks are preferably used in the form of sheet. The fusible material used for the blank need not have any elastomeric qualities.

Fusible materials which might be used as blanks would include natural and synthetic thermoplastic resins and thermosetting resins, glass and low melting elemental metals and alloys and compounds thereof.

The natural resins would include materials such as asphalt, bitumen, gums, pitch and tar.

The synthetic resins would include the vinyl resins. These vinyl resins may be either homopolymers of an individual vinyl monomer or they may be interpolymers of one or more vinyl monomer and from 0 to about 50 mol per cent of one or more non-vinyl monomers which are interpolymerizable with vinyl monomers. The term "vinyl monomer" means a compound which contains at least one polymerizable group of the formula

$$-\overset{|}{C}=\overset{|}{C}-.$$

Such vinyl monomers, therefore, would include the following: unsubstituted olefins, including mono-olefins such as ethylene, propylene, 1-butene, and isobutylene and polyolefins such as butadiene, isoprene, dicyclopentadiene and norbornene; halogenated olefins such as chloroprene, tetrafluoroethylene, chlorotrifluoroethylene, hexafluoropropylene; vinyl aryls such as styrene, *o*-methoxystyrene, *p*-methoxystyrene, *m*-methoxystyrene, *o*-nitrostyrene, *p*-nitrostyrene, *o*-methylstyrene, *p*-methylstyrene, *m*-methylstyrene, *p*-phenylstyrene, *o*-phenylstyrene, *m*-phenylstyrene, vinylnaphthalene and the like vinyl and vinylidene halides, such as vinyl chloride, vinyl fluoride, vinylidene chloride, vinylidene fluoride, vinylidene bromide and the like; vinyl esters such as vinyl formate, vinyl acetate, vinyl propionate, vinyl butyrate, vinyl chloroacetate, vinyl chloropropionate, vinyl benzoate, vinyl chlorobenzoate and the like; acrylic and *alpha*-alkyl acrylic acids, their alkyl esters, their amides and their nitriles such as acrylic acid, chloroacrylic acid, methacrylic acid, ethacrylic acid, methyl acrylate, ethyl acrylate, butyl acrylate, *n*-octyl acrylate, 2-ethylhexyl acrylate, *n*-decyl acrylate, methyl methacrylate, butyl methacrylate, methyl ethacrylate, ethyl ethacrylate, acrylamide, N-methyl acrylamide, N,N-dimethyl acrylamide, methacrylamide, N-methyl methacrylamide, N,N-dimethyl methacrylamide, acrylonitrile, chloroacrylonitrile, methacrylonitrile, ethacrylonitrile, and the like; maleic and fumaric acid and their anhydrides and alkyl esters such as maleic anhydride, dimethyl maleate, diethyl maleate and the like; vinyl alkyl esters and ketones such as vinyl methyl ether, vinyl ether, vinyl isobutyl ether 2-chloroethyl vinyl ether, methyl vinyl ketone, ethyl vinyl ketone, isobutyl vinyl ketone and the like; also vinyl pyridine, N-vinyl carbazole, N-vinyl pyrrolidone, ethyl methylene malonate, acrolein, vinyl alcohol, vinyl acetal, vinyl butyral and the like. Non-vinyl monomers which may be interpolymerizable with vinyl monomers include carbon monoxide and formaldehyde.

The vinyl polymers would thus include, for example, polyethylene, polypropylene, ethylene-propylene copolymers, polyvinyl chloride, polyvinylidene chloride, polyvinyl fluoride, polystyrene, styrene-butadiene-acrylonitrile terpolymers, ethylene-vinyl-acetate copolymers, ethylene-acrylic acid copolymers, ethylene-acrylonitrile copolymers and styrene-acrylonitrile copolymers.

In addition to the vinyl polymers, other polymeric materials which may be used in accordance with the present invention include thermoplastic polyurethane resins; polyamide resins, such as the nylon resin, including polyhexamethylene adipamide; polysulfone resins; polycarbonate resins; phenoxy resins; polyacetal resins; polyalkylene oxide resins such as polyethylene oxide and polypropylene oxide; polyphenylene oxide resins; and cellulose ester resins such as cellulose nitrate, cellulose acetate and cellulose propionate.

Also included within the term "polymer"

are blends of two or more polymeric materials. Illustrative of such blends are polyethylene/polypropylene; low density polyethylene/high density polyethylene; polyethylene with olefin interpolymers such as those indicated above, for example, ethylene-acrylic acid copolymers, ethylene-ethyl methacrylate copolymers, ethylene-ethylacrylate copolymers, ethylene-vinyl acetate copolymers, ethylene-acrylic acid-ethylacrylate terpolymers, ethylene-acrylic acid-vinylacetate terpolymers, and the like.

Also included within the term "polymer" are the metallic salts of those polymers or blends thereof which contain free carboxylic acid groups. Illustrative of such polymers are ethylene-methacrylic acid copolymers, ethylene-acrylic acid copolymers, styrene-acrylic acid copolymers, butene-acrylic acid copolymers, and the like.

Illustrative of the metals which may be used to provide the salts of such carboxylic acid polymers are the 1, 2, and 3 valent metals such as sodium, lithium, potassium, calcium, magnesium, aluminum, barium, zinc, zirconium, beryllium, iron, nickel, cobalt, and the like.

The polymers from which the blanks are shaped may be used in any of the forms in which they are commonly employed in the molding arts such as in the form of powder, pellets, granules and the like, and blends of the same with one or more adjuvant materials. Such adjuvant materials would include materials such as plasticizers, heat and light stabilizers, fillers, pigments, processing acids, extenders, fibrous reinforcing agents, impact improvers and metal, carbon and glass fibers and particles.

The particular polymeric material being used would dictate the selection and quantity of the adjuvants to be employed therewith, since it is the respective adjuvants for such polymers that are employed in the present invention. The adjuvants employed must be physically and chemically compatible with each of the other components of the compositions under the described operating conditions. The adjuvants are used in amounts which will be effective for the intended purpose. Thus, for example, the effective amount of plasticizer is a "plasticizing amount", that is, an amount of plasticizer which will appreciably increase the flexibility, processability, workability and/or distensibility of the polymer. The stabilizers would be used in a stabilizingly effective quantity, and the fillers would be used in effective quantities therefor, as for example, if a reinforcing filler is to be used then the filler would be used in such amounts as to provide the desired reinforcing effect.

The polymer based compositions employed in the present invention may be prepared by any of the commonly employed techniques employed for compounding such compositions. Such procedures would include techniques such as dry blending or hot compounding, as well as with or without the use of mixing equipment such as ribbon blenders, muller blenders, intensive mixer blenders, extruders, banbury mixers and the like.

Although metallic materials of construction are usually only used as the mold plates in the process of the present invention, it is possible that blanks of the present invention can also be made wherein a low melting metal, or alloy or compound thereof, can be used as the blank with mold plates made from non-fusible materials, or materials having higher fusion points than such low melting metallic materials.

Some rigid polymeric materials such as polysulfone resins, polycarbonate resin, and certain vinyl resins such as polyvinyl chloride, tend to develop locked-in strains when press formed into blanks. When such strains are present, it is not possible to readily use the blanks in the process of the present invention unless the blanks are first annealed to relax such strains in the blank. This annealing can be accomplished in about 0.5 to 240 minutes at temperatures ranging from the heat distortion temperature to the melting point of the resin.

Where the compositions used for the thermoformable blank contains fillers, the expansion temperature may have to be increased 5 to 20°C. to compensate for the increased viscosity of the resulting compositions.

The two mold plates used to pull the blank apart can be made of the same or different materials. The mold plates may have continuous or channeled surfaces, as noted above, they may also be porous or non-porous. A porous top mold plate may be used for venting purposes when the channeling means is a negative type channeling means. The channels may be straight or arcuate, and in a pattern or labyrinthian.

During the molding operation it is desirable as noted above, to vent the interior portions of the blanks which are being pulled apart. The need for venting the blanks being expanded, as noted above, arises due to the fact that a vacuum is created within the interior sections of the blank by virtue of the increase of the volume of such interior portions during the expansion operation. If the blank is not vented during the expansion operation, atmospheric pressure could cause puncture of the extended rib sections of the expanded blank during the expansion operation. This venting of the expanded blank can be accomplished by using channeled or porous mold plates.

The materials from which the mold plates may be fabricated are normally solid materials which are either not fusible at the operating temperatures or which have a melting point

which is at least 10°C. higher than the melting point of the fusible material from which the blank is fabricated.

Non-fusible materials which may be used for the mold plates would include cellulosic materials such as wood, paper, cardboard and compressed sawdust; thermoset or vulcanized compositions based on natural or synthetic resins; minerals such as graphite, clay and quart; natural rock and stone materials such as marble and slate; building materials such as brick, tile, wallboard and concrete; and proteinaceous materials such as leather and hides.

Fusible materials having a relatively high Tg or Tm which could be used as the mold plates would include metals such as aluminum, iron, lead, nickel, magnesium, copper, silver and tin, as well as alloys and compounds of such metals, such as steel, brass and bronze; vitreous materials such as glass, ceramics and porcelain; and thermoplastic resins having a relatively very high fusion point, such as the so called engineering plastics, such as polytetrafluoroethylene, nylon-6 resins, polyacetal resins, polyvinylidene fluoride, polyesters and polyvinyl fluoride; or fusible materials coated with polytetrafluoroethylene.

The use of mold release agents such as silicone oils and fluorocarbon oils, or the use of mold plates made of materials having a low surface energy such as polytetrafluoroethylene, will insure the separation of the cooled expanded blank from the mold plates after the expansion operation, when the cooled expanded blank would not otherwise readily separate from the mold plates.

As noted above, one or both of the surfaces of the plates which are used to adhere to, and pull and expand the blank of plastic, may be an integral part of the press platens or molding device. One or both of the mold plates may also be removably mountable on the pattern or molding device. The use of the removable type of mold plate is preferable where the mold plates are to be channeled or porous, so as to effect the venting therethrough.

The following examples are merely illustrative of the present invention and are not intended as a limitation upon the scope thereof.

The press used in these examples was a spring loaded Carver press, as shown in Figures 2 to 4 of the drawings. Two springs were used in the press and each had a deflection of 130 pounds per inch, and the springs were designed to mechanically pull the platens apart, as explained above with reference to Figures 2 to 4, at a predetermined rate, as regulated by a needle valve on the hydraulic ram of the press. The platens of the press were malleable cast iron and could be cooled by conduction, as desired, by the circulation of cold water therethrough. The platens of the press could also be heated by conduction, as desired, by heating platens 5A and 5B electrically. Top mold plate 1 was made of aluminum. The temperature of the surfaces of both the heated platens and the mold plates were measured with a thermocoupled pyrometer.

EXAMPLES 1—8

Eight blanks, in the form of 6″×6″ plaques, of eight different thermoplastic materials were expanded as disclosed above with respect to Figures 1 to 4, inclusive, to produce expanded objects as disclosed in Figures 5—7. The blanks were of various initial thicknesses, and they were expanded to various heights. Table I below lists:

a) the polymeric material used in each plaque;
b) the Ta of each such polymeric material, in °C.;
c) the initial thickness, in mils, of the plaque when it was inserted in the press;
d) the temperature of the platens and upper mold plate when the plaque was inserted in the press;
e) the temperature of the platens, upper mold plate, and plaque at the start of the expansion step in the process;
f) the final thickness of the expanded blank, in mils;
g) comments on the flexibility or rigidity, and on the clarity or color of the resulting expanded blank.

During the expansion process the blanks were expanded at the rate of about 15—20 mils per second.

TABLE I

Example	Polymer	Ta—°C	Initial Thickness mils	Insertion Temp. °C.	Expansion Temp. °C.	Expanded Thickness mils.	Comments
1	polycarbonate	320	80	280	270	240	rigid, black
2	94.2/5.7 ethylene-ethyl acrylate copolymer	110	60	140	130	240	very flexible, clear
3	polymethylmethacrylate	160	120	180	180	630	rigid, clear
4	thermoplastic polyurethane polyether	160—180	100	170	160	310	very flexible somewhat opaque yellow
	Nylon-6	240	65	250	240	325	moderately flexible, relatively opaque
6	polystyrene	185	60	190	185	240	rigid — clear
7	(rigid) polyvinylchloride	155	130	205	195	650	rigid, clear, yellow
8	polyethylene 0.96 density 4 melt index	135—140	60	160	150	300	rigid — clear

Notes:

1. The polymeric material used in Example 1 was General Electric Co's. Lexan polycarbonate which was filled with 4% by weight of carbon black.

2. The plaque of polyvinyl chloride used in Example 7 was annealed at 150°C. for 5 minutes prior to be inserted in the press to remove stresses therein.

EXAMPLE 9

This example discloses the preparation of an expanded article 12 as shown in Figure 9. The expanded article was prepared from a 60 mil thick sheet of impact grade polystyrene which had a Ta of 180°C. The expanded article was prepared from four strips of the polystyrene, each of which were 3/8" wide and 3" long. The strips were then placed on the lower platen 5B of the Carver press so as to form a hollow square measuring 3-3/8" on each of the four sides thereof. During the step in the process as shown in Figure 3 where the top mold 1 and lower platen 5B are brought together to fuse and slightly compress the blank, the four strips of polystyrene were fused together at the four seams 12B, by dotted lines or arrows in Figure 9. The polystyrene strips were inserted in the press when it was heated to 210°C., and the fused square of polystyrene strips was then expanded at 200°C. to a height of 300 mils to produce a unitary rigid expanded article 12 as shown in Figure 9.

EXAMPLE 10

This example discloses the preparation of an expanded article 17 as shown in Figure 10. The expanded article was prepared from a 60 mil thick sheet of impact grade polystyrene which had a Ta of 180°C. The expanded article was prepared from a hollow circular blank which was punched out of a continuous sheet of the polymer so as to provide a ring shaped blank having an inner diameter of one 1-7/8". The continuous solid portion of the ring thus had a width of 7/16". This punched out ring shaped blank was then inserted in the press at 210°C. and expanded at 200°C. to a height of 300 mils to produce a unitary rigid expanded article 17 as shown in Figure 10.

The amount of pressure used to pull the plates of the press apart in the process of the present invention is about 1 to 10 pounds per square inch of continuous surface area on the blank contact surface of the plates.

Various polymeric resins used as the expandable blanks tend to pick up moisture when exposed to the atmosphere, i.e., about 0.05 to 5.0 weight %. This moisture is preferably removed from the plastic before inserting the plastic in the hot press so as to avoid blistering or bubbling in the heated plastic. The plastics which are more susceptible to this type of moisture absorption are the polycarbonate resins, polymethylmethacrylate resins, nylon resins, cellulose acetate resins, acrylonitrile - butadiene - styrene terpolymer resins, hydroxy propyl cellulose resins, styrene-acrylonitrile copolymer resins and phenoxy resins.

WHAT WE CLAIM IS:—

1. A process for integrally forming a bristled article from a blank of thermoformable material having a Ta (as hereinbefore defined) in the form of a sheet having a top surface and a bottom surface which comprises
   - inserting said blank between a top mold plate and a bottom mold plate, each of said mold plates having a surface for contacting the top and bottom surfaces of said blank, and each of said mold plates having a fusion point which is higher than the Ta of said thermoformable material,
   - the blank contacting surface of said bottom mold plate being continuous, and the blank contacting surface of said top mold plate having a pattern of channel means therein, said channel means being used to provide a pattern of channels at the interface between the top surface of said blank and the blank contact surface of the top mold plate, such pattern providing areas of contact between the top surface of the blank and the blank contact surface of the top mold plate at the non-channeled areas of said top mold plate, and such pattern also providing areas of non-contact between the top surface of the blank and the blank contact surface of the top mold plate, at the channeled areas of said top mold plate,
   - heating said blank to at least its Ta so as to adhesively bond said blank by hot tack adhesion to the blank contacting surfaces of said mold plates,
   - pulling said mold plates apart while said blank is thus adhesively bonded thereto so as to draw a portion of the thermoformable material from the blank in the form of a plurality of discrete bristle-like elements, the pattern of occurrence of said bristle-like elements being determined by the pattern of areas of contact between the top mold plate and the blank, said pulling apart effecting partial vacuum conditions between said bristle like elements, venting said channels during said pulling apart so as to equilibrate the lower level of pressure within said channels with the higher level of ambient pressure without said channels so as to thereby regulate the uniformity and integrity of the configuration of the bristle-like elements,
   - cooling the resultant expanded blank to a temperature below the heat distortion temperature of said thermoformable material.

2. A process as in claim 1 in which said channels are arranged in a grid pattern.

3. A process as in claim 1 or 2 in which the blank contacting areas on the blank contacting surface of said top mold plate are angular.

4. A process as in claim 3 in which the blank contacting areas on the blank contacting surface of said top mold plate are rectangular.

5. A process as in any one of the preceding claims in which the two mold plates are pulled apart so as to provide bristle like elements of uniform height.

6. A process as in any one of the preceding claims in which the blank contains internal stresses and is annealed to remove said stresses therefrom prior to expanding blank.

7. A process as in any one of the preceding claims in which said channel means comprise recessed channels.

8. A process as in claim 7 in which said recessed channels are interconnected.

9. A process as claimed in any one of the preceding claims in which the cooled expanded blank is separated from one or both of said mold plates.

10. An article integrally formed from thermoformable material by a process as claimed in any one of the preceding claims, said article comprising a continuous base member, and a plurality of bristle-like members projecting vertically from at least one side of said base member, each of said bristle-like members having an I beam configuration.

11. An article as claimed in claim 10 in which all of said bristle-like members project from the same side of said base member.

12. An article as claimed in claim 10 or 11 in which said bristle-like members are in an ordered arrangement.

13. An article as claimed in claim 12 in which said bristle-like members are arranged in columns.

14. An article as claimed in claim 13 in which said bristle-like members are arranged in staggered columns.

15. An article as claimed in any one of claims 10 to 14 in which said bristle-like members are longer than they are wide.

16. An article as claimed in any of claims 10 to 15 in which all of said bristle-like members are of uniform height.

17. An article as claimed in any one of claims 10 to 16 in which said thermoformable material comprises thermoplastic material.

18. An article as claimed in claim 17 in which said thermoplastic material comprises synthetic resin.

19. An article as claimed in claim 18 in which said synthetic resin comprises urethane resin.

20. An article as claimed in claim 18 in which said synthetic resin comprises vinyl resin.

21. An article as claimed in claim 20 in which said vinyl resin comprises hydrocarbon resin.

22. An article as claimed in claim 21 in which said hydrocarbon resin comprises polyethylene.

23. An article as claimed in claim 21 in which said hydrocarbon resin comprises polystyrene.

24. An article as claimed in claim 20 in which said vinyl resin comprises ethylene-ethyl acrylate copolymer.

25. An article as claimed in claim 20 in which said vinyl resin comprises polymethylmethacrylate.

26. An article as claimed in claim 20 in which said vinyl resin comprises polyvinylchloride.

27. An article as claimed in claim 18 in which said synthetic resin comprises polycarbonate resin.

28. An article as claimed in claim 18 in which said synthetic resin comprises nylon resin.

29. An article as claimed in any one of claims 10 to 28 which is flexible.

30. An article as claimed in any one of claims 10 to 28 which is rigid.

31. A packaged article comprising an article as claimed in any one of claims 10 to 30 as the packaging means.

32. A zipper-like article comprising a flexible article as claimed in claim 29 and a rigid article as claimed in claim 30.

W. P. THOMPSON & CO.,
Church Street,
Liverpool, L1 3AB,
Chartered Patent Agents.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1976.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1424337 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

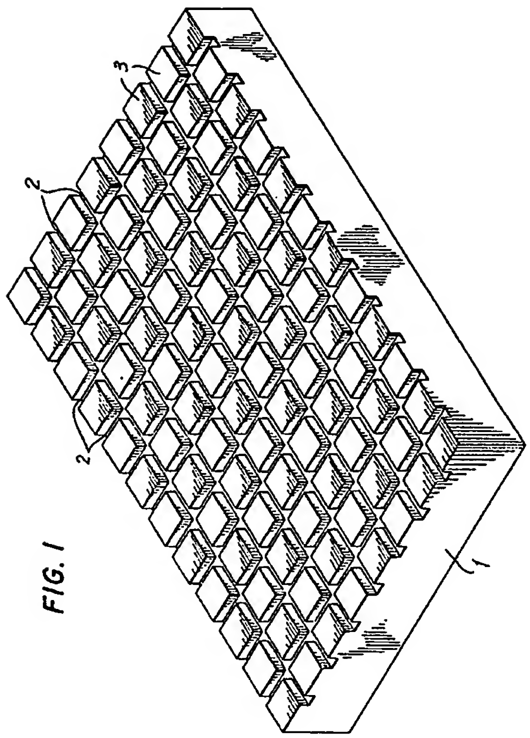


FIG. 1

FIG. 2

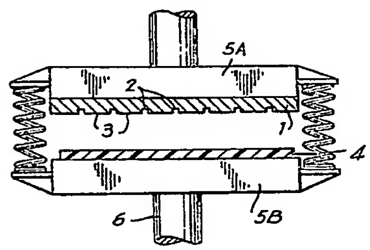


FIG. 3

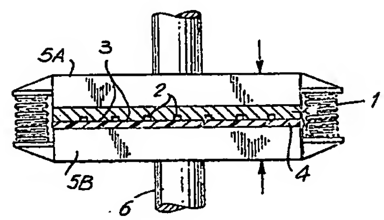
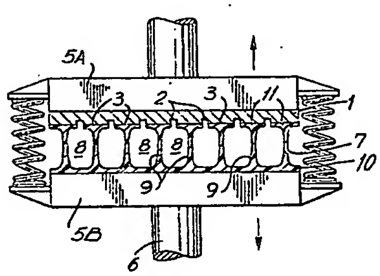


FIG. 4



1424337 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

FIG. 5

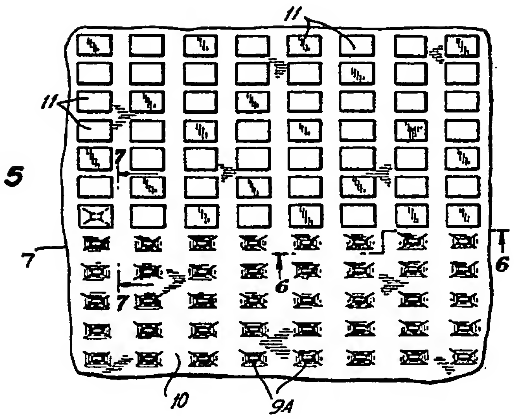


FIG. 6

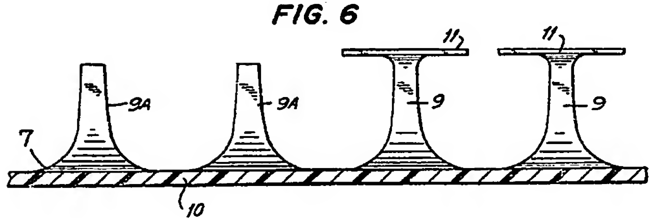


FIG. 7

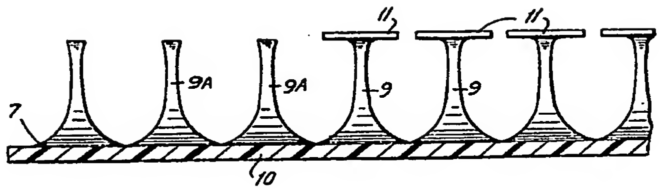


FIG. 8

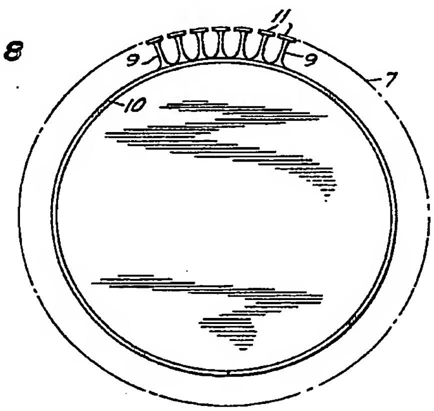


FIG. 9

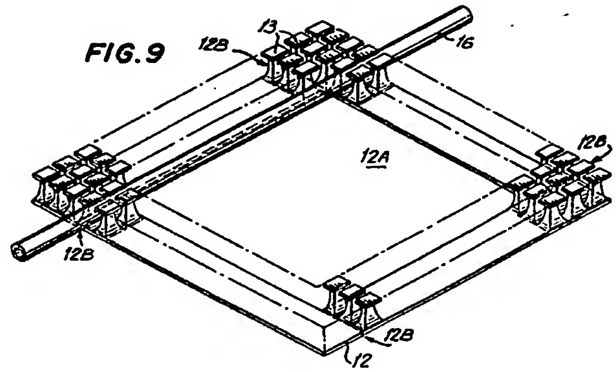


FIG. 10

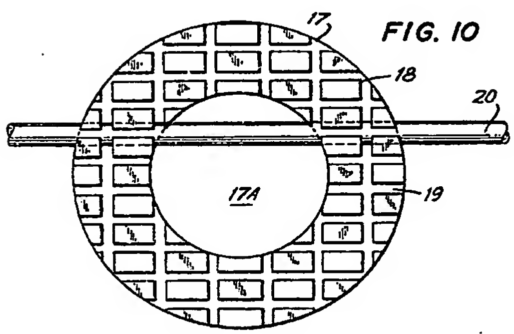
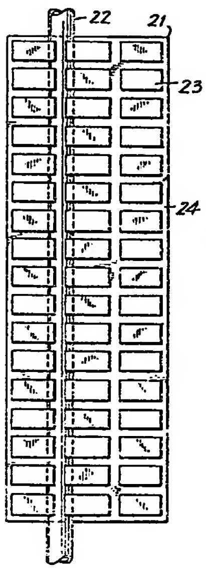


FIG. 11



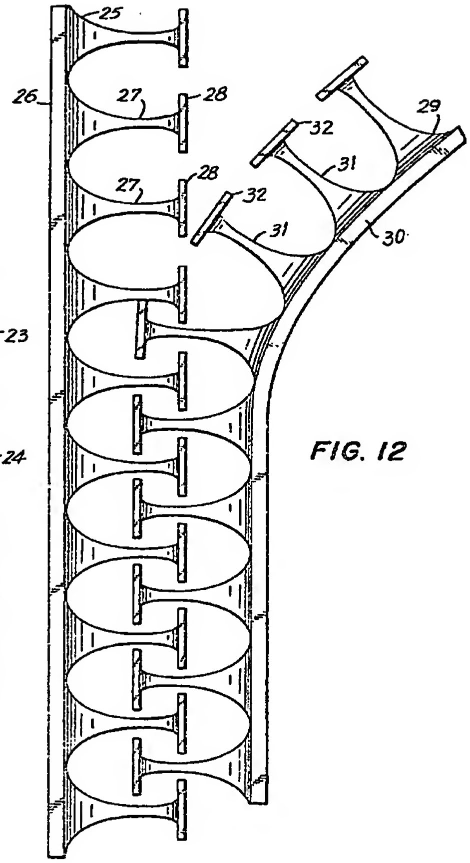


FIG. 12